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Welding Nickel Base Alloys

Welding parameters are established for the gas tungsten-arc and resistance spot welding of thin gage René 41 and Hastelloy X

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Introduction

Planning for re-entry and for supersonic cruise vehicles indicates that extensive use of high temperature resistant materials will be required in the foil and medium gages. The nickel-base alloys, due to their strength at high temperatures and oxidation resistance properties, are candidate materials for these applications. They are readily available in the desired gages. However, the fabrication of these materials for missile and space vehicle applications will require extensive fusion and resistance welding for fastening. Thus the object of this project was to develop welding parameters for joining nickel-base alloys in the thin gages by the gas tungsten-arc and resistance spot welding methods. René 41 and Hastelloy X alloys were selected because of their potential use and their current availability.

Background

The chemical compositions of the selected alloys appear in Table 1. These alloys are resistant to oxidizing, reducing and neutral atmospheres.

The optimum application condition for Hastelloy X alloy exists in the solution heat treated condition. Solution heat treatment is obtained by heating to 2150° F, followed by either a rapid air cool or water quench. Aging is not recommended. The normal room temperature tensile stength is 110,000 psi. It is usually selected for its oxidation resistance and strength capabilities at elevated temperatures, and for its good forming and welding characteristics.

The René 41 alloy possesses good strength in the 1200 and 1800° F temperature range. The maximum room temperature strength in the solution heat treated condition is approximately 170,000 psi. Solution heat treatment is obtained by heating to 1950° F, holding 4 hr followed by rapid air cooling. Aging at 1400° F for 16 hr may produce room temperature strength in excess of 200,000 psi. Assurance of consistent properties results from close control of interstitial and chemical elements by the arc vacuum remelting process.

Both alloys are ductile and can be formed readily. However, they do require higher forming pressures than the stainless steels, and stress relief heat treatment may be required after each cold work forming step.

Published information has shown that these alloys are weldable by either the gas tungsten-arc or resistance welding processes.

Equipment

The welding equipment used for this project was of a type normally found in aircraft and missile production facilities. Equipment used for shearing, flanging and butt welding of foil gages must be precision and limited to the foil gages exclusively.

The resistance spot welding of foil and medium gage material was done with a special scissors-type portable gun. The transformer was 150 kva, controlled by a 3 phase, 10 cycle, frequency converter digital timing control. Optimum welding heat settings were possible because of separate full range phase shift and timing controls for preheat, weld, post heat and temper functions.

The foil butt welding was done on a precision foil butt welding unit with a semiautomatic gas tungsten-arc welding electrode holder and a $^1/_4$ to 10 amp filtered d-c power supply. Arc initiation at these low currents was accomplished with a tuned oscillator high frequency unit. The maximum variation of travel carriaged in the horizontal and vertical plane was less than $^1/_4$ mil.

The butt welding of the medium gage material was done on a standard stake welding unit with a semi-automatic tungsten-arc welding electrode holder and a 300 amp a-c, d-c power supply. The stake unit was a standard production-type facility.

Table 1—Chemical Composition of René 41 and Hastelloy X, %

Element	René 41	Hastelloy X
Chromium	18.0–20.0	20.5–23.0
Iron	5.0 max.	17.0–20.0
Cobalt	10.0–12.0	0.5–2.5
Titanium	3.0–3.3	...
Molybdenum	9.0–10.5	8.0–10.0
Aluminum	1.5	...
Tungsten	...	0.2–1.0
Carbon	0.12 max.	0.05–0.15
Silicon	0.50 max.	1.0 max.
Manganese	...	1.0 max.
Nickel	Bal. (approx. 50)	Bal. (approx 47)

Test Procedure

Welding parameters were developed for resistance spot and gas tungsten-arc fusion welding of each alloy in 0.005, 0.010 and 0.040 in. thicknesses. The welding schedules developed are suitable for production applications of flat and cylindrical sections. Three-piece tee sections were tungsten-arc welded to simulate attachment problems.

Extreme care was exercised in the edge preparation of the foil material to attain or preserve the conditions necessary for butt welding. Alignment of the butt edges to obtain contact throughout the length of the weld was essential.

Mechanical test data were compiled for the properties of welds made on material in the solution treated condition, solution treated and aged condition and solution treated welded and then aged condition. Tensile properties were correlated according to the direction of rolling. All test data was comared to base material control coupons for which physical data are listed in Table 2.

Representative photomicrographs

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Table 2—Mechanical Property Data of Base Metal Control Coupons

Thickness, in.	Direction of shearing to rolling	René 41 Yield strength, psi	René 41 Ultimate strength, psi	René 41 Elong. in 2 in., %	Hastelloy X Yield strength, psi	Hastelloy X Ultimate strength, psi	Hastelloy X Elong. in 2 in., %
Solution Heat Treated							
0.005	Transverse	75,100	138,100	31.8	62,266	119,466	26.8
0.005	Parallel	74,866	138,066	33.8	63,033	120,930	27.7
0.010	Transverse	61,366	134,866	41.2	53,770	112,830	37.2
0.010	Parallel	62,733	134,866	47.8	53,400	113,400	39.5
0.040	Transverse	75,600	140,500	37.3	56,800	113,710	39,2
0.040	Parallel	79,433	141,456	43.3	61,100	113,130	41.7
All coupons bent over IT thickness showed no apparent cracks							
Solution Heat Treated & Aged[a]							
0.005	Transverse	132,900	172,900	9.0	60,000	94,000	5.0
0.010	Transverse	121,600	161,200	7.5	53,100	100,000	12.5
0.040	Transverse	143,400	185,300	11.0	64,470	118,420	29.0

[a] René 41 aging cycle: 1400° F. for 16 hr—air cool; Hastelloy X aging cycle: 1500° F for 10 hr—air cool.

were taken of each test series. All René 41 metallographic specimens were etched with Marbles reagent. The Hastelloy X specimens were etched with hot aqua regia. All photomicrographs of weld structures were made at 40 or 50 diameters magnification.

Foil Gage Tungsten-Arc Welding

Initial welding trials on the 0.005 and 0.010 in. thick material used square butt joints. It was impossible to weld the 0.005 in. material because of overlap during welding which caused burn-through, arc wander and lack of penetration. The 0.010 in. material could be welded in 8 in. lengths by tacking prior to welding. Longer lengths would overlap prior to completing the weld.

Due to lack of slitting and flanging facilities, the material was finished sheared with a 0.016 in. standing flange. This was accomplished by placing a 0.016 in. spacer strip on the shear platen; the foil material was then clamped to the platen under a stiffened straight edge and a final $^1/_4$ in. shear cut was made. This method produced an edge with a uniform standing flange and a sharp radius. It was adequate for welding 0.005, 0.010 up to 0.016 in. material but ... desired precision for thinner ...

With the 0.016 in. flange pr... tion, welds were made in 8 and ... lengths. Table 3 contains the ... chanical properties and weld sch... ules. The face of the welds ... medium reinforcements and the r... of the welds had light drop throu... The René 41 and Hastelloy X c... sections are visible in Figs. 1 and ... spectively. The face and ... surfaces were clean and bright ...

Fig. 1—Top: 0.005 in. Rene' 41 flange butt weld (test 2). Bottom: 0.010 in. Rene' 41 square butt weld (test 4)

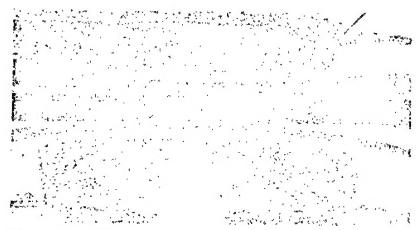

Fig. 2—0.005 and 0.010 in. Hastelloy X flanged butt welds (tests 5 and 7)

Table 3—Mechanical Properties and Weld Schedules of Solution Heat Treated and Butt Welded Foil Gage Material

Test	Material	Gage,[a] in.	Testing to rolling direction[b]	Yield strength, psi	Ultimate strength, psi	Elong in 2 in., %	Location of fracture[c]	Weld efficiency,[d] %	Loss of elongation,[e] %	180 deg bend over IT[f]
1	René 41	0.005	Parallel	78,300	129,300	20.3	HA	93.5	40.0	No cracks
2	René 41	0.005	Transverse	74,300	114,809	16.3	P & HA	83.0	48.0	No cracks
3	René 41	0.010	Parallel	85,766	131,600	29.5	W	97.5	34.2	No cracks
4	René 41	0.010	Transverse	69,000	129,500	27.5	W	96.5	33.2	No cracks
5	Hastelloy X	0.005	Parallel	62,270	97,030	8.2	HA	80.2	70.4	No cracks
6	Hastelloy X	0.005	Transverse	63,870	108,530	24.0	HA, P, W	90.8	10.4	No cracks
7	Hastelloy X	0.010	Parallel	53,170	120,430	33.8	P	100.0	14.4	Slight crackin[g]
8	Hastelloy X	0.010	Transverse	53,270	105,300	21.5	P	93.3	41.4	No cracks

Welding schedule

Test	Speed, ipm	Current, amp	Arc, volts	Argon, cfh Shielding	Argon, cfh Backing
1	6	4	2	8	8
2	6	4	2	8	8
3	6	9	2	12	12
4	6	9	2	12	12
5	6	4	2	8	8
6	6	4	2	8	8
7	6	9	2	12	12
8	6	9	2	12	12

[a] Coupons ground flush at welds.
[b] Welds 90 deg to testing direction.
[c] HA—heat-affected zone; P—base metal; W—weld.
[d] Percent weld efficiency = [ultimate psi (weld coupon) × 100] (ultimate psi (base metal coupon).
[e] Percent loss of elongation = [Percent elong. base metal-percent elong weld coupon) × 100] (percent elongation base metal).
[f] Face and root bends were made with axis of bend parallel to weld direction; radiographs of all samples were acceptable.

ept that the René 41 weldments had small irregular areas which were dull and slightly rough. This condition is typical of René 41 weldments and does not appear to be detrimental.

There was very little difference between yield strength, ultimate strength, and elongation with respect to the rolling direction. The René 41 material displayed good weldability with good physical results. The elongation ranged from 16 to 25% with 85 to 97% weld efficiency. The Hastelloy X material, except for Test 5, displayed good weldability with elongation ranging from 21.5 to 33.8% with 90.8 to 100% weld efficiency. These test results were more consistent than those of the René 41. Test 5, however, showed much lower strength and percent elongation results. The coupons of test 5 fractured in the heat-affected zone. The low results were due, primarily, to a notch at the root of the weld created by the radius of the flange. This condition can be corrected by greater heat input to extend the fusion zone or shorter flange height, and a smaller flange radius. The notch condition is located at the arrow in Fig. 2.

Since all the elongation measurements were made on 2 in. gage lengths, the elongation values represent an overall condition including weldment, heat-affected zone and base metal.

Test Results Obtained with Tungsten-Arc Process on 0.040 in. Material

Tests were made to determine the weldability of the medium gage materials of the same alloys, with and without filler metal and to determine the effects of the rolling direction.

The mechanical test results are tabulated in Table 4. The tests made parallel to the direction of rolling are slightly higher in strength and elongation values than those made transverse to the rolling direction. The differences are not great enough, however, to be of concern in design and application. The test results of specimens welded with and without filler metal are nearly equal. Therefore, filler metal is beneficial only to prevent thinning due to weld shrinkage and undercutting which occur on heavier sections due to higher heat input.

Mechanical test data indicate weld efficiencies ranging from 89.5 to 93.9% and elongation ranging from 19.3 to 26.2% for the René 41. The Hastelloy X ranges from 99.4 to 100% weld efficiency and from 23.3 to 38.8% elongation. Welds made with Hastelloy W filler metal cracked heavily when bent over a 2T radius. Slight cracking occurred during bending the other welds with a 2T radius indicating that a 2T bend for welded 0.040 in. thick material was too drastic. The Hastelloy X welds were cleaner and smoother than the welds of René 41. Microstructures of the René 41 and Hastelloy X, without filler metal addition, are shown in Figs. 3 and 4 respectively. Figures 5 and 6 show the Hastelloy X square butt welds made with Hastelloy X and Hastelloy W filler metal respectively. Some segregation appears in the weld made with the Hastelloy W filler metal at the arrow of Fig. 6.

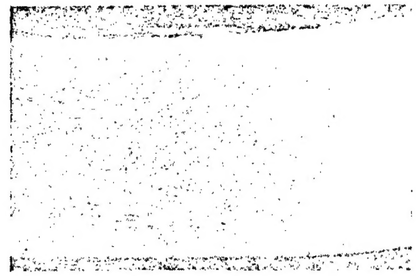

Fig. 3—0.040 in. Rene' 41 square butt weld. No filler metal (test 11)

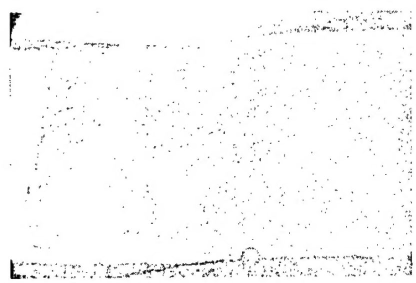

Fig. 4—0.040 in. Hastelloy X square butt weld. No filler metal (test 14)

Table 4—Mechanical Properties and Weld Schedules of Solution Heat Treated and Butt Welded 0.040 in. Material[c]

Test	0.040 material	Filler metal diameter, in.	Testing to rolling direction	Yield strength, psi	Ultimate strength, psi	Elong. in 2 in., %	Location of fracture	Weld efficiency, %	Loss of elongation, %	180 deg bend over 2T
9	René 41	0.040[a]	Parallel	77,230	132,890	26.2	W	93.9	39.5	Slight cracking
10	René 41	0.040[a]	Transverse	74,030	125,750	19.3	W	89.5	48.3	Slight cracking
11	René 41	none	Parallel	77,070	132,490	23.2	W	93.7	46.3	Slight cracking
12	Hastelloy X	0.040[a]	Parallel	59,920	115,010	38.8	P	100.0	7.0	Slight cracking
13	Hastelloy X	0.040[a]	Transverse	59,790	109,860	23.2	W	96.6	40.8	Slight cracking
14	Hastelloy X	none	Parallel	60,550	112,410	28.8	W	99.4	30.9	Slight cracking (face)
15	Hastelloy X	0.040[a]	Parallel	63,320	113,580	34.7	P, W	100.0	16.8	Heavy cracking face
16	Hastelloy X	0.040[a]	Transverse	59,020	114,310	33.3	P, W	100.0	15.1	Heavy cracking root

Welding schedule

Test	Speed ipm	Current, amp	Arc, volts	Argon cfh Shielding	Argon cfh Backing	Wire speed, ipm
9	8	45	8	17	8	7
10	10	45	8	16[b]	20	10
11	13	45	8	18	12	...
12	10	45	8	16	15	14
13	10	45	12	16[b]	15	14
14	12	30	8	15[b]	5	...
15	15	55	8	18	8	16
16	15	55	8	18	8	$17^1/_2$

[a] Filler metal of same material welded except Tests 15 and 16 which were Hastelloy W wire.
[b] Plus 10 cfh helium gas.
[c] Notes of Table 3 also apply to this table.

Hastelloy W contains higher percentages of nickel and molybdenum and lower percentages of chromium and iron than Hastelloy X.

Test Results Obtained on Welded and Aged Material

When comparing the tensile properties of the aged coupons of Table 2

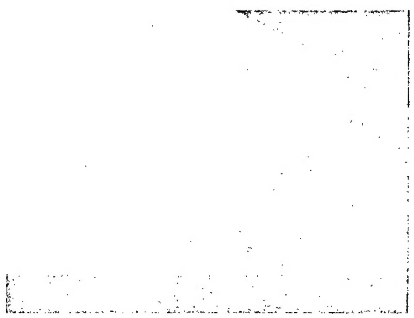

Fig. 5—0.040 in. Hastelloy X square butt weld with Hastelloy X filler metal (test 13)

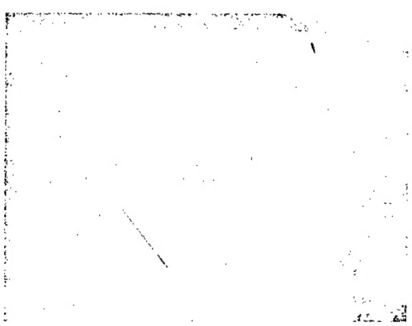

Fig. 6—0.040 in. Hastelloy X square butt weld with Hastelloy W filler metal (test 16)

to the base metal properties, it is noted that the René 41 aged coupon changed in relation to the solution treated base metal values approximately as follows: yield strength increase—75%; ultimate strength increase—25%; elongation decrease—71%. The change resulting from aging the Hastelloy X is erratic with respect to the yield and ultimate strength. However, an 80% decrease in elongation occurred.

The mechanical properties of the welded and aged coupons are tabulated in Table 5. The René 41 weld coupons aged after welding had weld efficiencies ranging from 96.3 to 100% and elongation ranging from 5.3 to 9.2%. Test 11.2 which was welded in the aged condition had a weld efficiency of 76.4% and an elongation of 3.7%. The low elongation was due primarily to the fact that the elongation was restricted to the weld and heat-affected zone which encompasses under 1/2 in. while the measurement was gaged over the 2 in. length. The low weld efficiency was due in part to the unaged condition of the weldment.

These test results indicate that aging of welded René 41 structures can be accomplished with good benefits and, if necessary, the welding of aged material is possible when the application allows for the resulting lower elongation. Aging Hastelloy X, welded or not, is nonbeneficial to the strength and detrimental to the elongation. Microstructures of

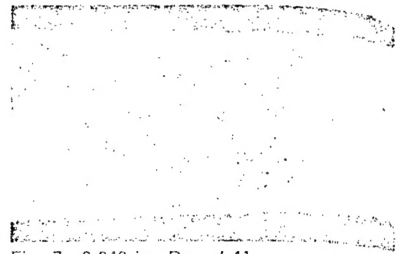

Fig. 7—0.040 in. Rene' 41 square butt weld aged after welding (test 11.1)

Fig. 8—0.005 and 0.010 in. Hastelloy X flanged butt welds aged after welding (tests 5.1 and 7.1)

the aged welds are shown in Fig. 7 and 8.

Welds and Circular Restraint Tests

Three-piece tee joints were welded to simulate the attachment of two edge members to a web center section. The welds were made with the center sections projecting one or two thicknesses above the two edge members, as recorded in Table 6, to provide for a burn-down joint. This furnishes the welds with light reinforcements on the face side and a fillet on each side of the centerpiece on the root side. Figure 9 shows the face and root side of tee weld

Table 5—Mechanical Properties of Solution Heat Treated Welded and Aged Coupons[a]

Test	Thickness, in. and material	Filler metal	Yield strength, psi	Ultimate strength, psi	Elong in 2 in., %	Location of fracture	Weld efficiency, %	Loss in elongation, %	Bend test data
1.1	0.005 René 41	0.016 in. flange	136,370	170,030	8.6	P & HA	98.5	45	180 deg—8T OK 180 deg—2T broke
3.1	0.010 René 41	0.016 in. flange	133,230	164,500	5.3	HA	100.0	28.4	180 deg—2T broke
9.1	0.040 René 41	0.040 in. wire	137,600	182,200	9.0	HA	97.7	16.4	90 deg—3T cracks
11.1	0.040 René 41	None	143,630	178,500	7.8	W	96.3	29.1	4T bend cracked betwee[n] 45 deg and 180 deg o[n] face
11.2[b]	0.040 Rene' 41	0.040 in. wire	106,090	141,630	3.7	W	76.4	66.4	180 deg—2T slight crack on face
5.1	0.005 Hastelloy X	0.016 in. flange	60,000	99,600	6.0	HA	100.0	0	180 deg—8T OK 180 deg—4T cracks
7.1	0.010 Hastelloy X	0.016 in. flange	52,670	95,030	8.0	P	95.0	36.0	180 deg—2T cracks
12.1	0.040 Hastelloy X	0.040 in. wire	56,550	115,112	25.8	P	98.9	11.0	90 deg—3T face OK not cracked
15.1[b]	0.040 Hastelloy X	0.040 in. wire[c]	58,460	117,090	25.8	P	98.9	11.0	3T root cracked at 60 de[g] 2T face cracked at 90 de[g]
16.1[a]	0.040 Hastelloy X	0.040 in. wire	59,500	111,510	18.0	W	42.2	37.9	180 deg—2T extensive cracks

[a] The notes of Table 3 also apply to Table 5.
[b] Aged before welding.
[c] Hastelloy W filler metal.

Table 6—Tee Joint Welds and Circular Restraint Tests

Test	Material	Gage	Weld	Center piece projection	Radiograph grading	Weld schedule[b] Amp	Volts	Speed, ipm	Shielding, cfh	Backing, cfh
17	René 41	0.005	Tee	2T	Local porous areas	10	8	5	12	...
18	René 41	0.010	Tee	2T	Acceptable	13	8	3	7	...
19	Hastelloy X	0.005	Tee	2T	Local porous areas	10	8	5	12	...
20	Hastelloy X	0.010	Tee	2T	Local porous areas	25	8	8	16	...
21	René 41	0.040	Tee	1T	Acceptable	60	9	8	18	8
22	René 41	0.040	Tee	1T	Acceptable[a]	60	8	8	12	5
23	René 41	0.040	Circular butt	..	Acceptable[a]	Manual welds				
24	Hastelloy X	0.040	Circular butt	..	Acceptable	Manual welds				

[a] Before and after aging.
[b] Argon gas.

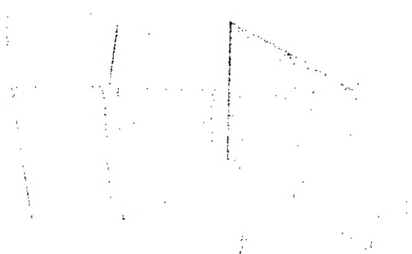

Fig. 9—0.040 in. Hastelloy X, 3 piece tee weld, face and root views (test 22)

made from 0.040 in. thick René 41 material. The welds have defects of irregular root penetration and lack of fusion at the root of the weld as shown respectively in Figs. 10 and 11.

The 0.005 and 0.010 in. thick plates were welded on a set of chill bars that had a square shoulder at the root of the weld. No backing gas was used. Champering this edge would allow the fillet to drop through further thus increasing penetration and eliminating the lack of fusion at the bottom of the fillet. Porosity which developed during welding, as shown in Table 6, could be eliminated by adding backing gas.

The lack of fusion of the 0.040 in. thick material could be corrected by adjustment of the heat input.

The welding was done in a fixture having copper chill bars on the bottom and copper hold down bars at the top. The welds were made with a semiautomatic gas tungsten-arc electrode holder driven on an extended track of a stake welding unit.

Circular restraint tests were made

Fig. 10—0.010 in. Rene' 41, 3 piece tee weld with irregular root penetration (test 18)

Fig. 11—0.040 in. Hastelloy X, 3 piece tee weld with lack of fusion at the fillets (test 22)

on the 0.040 in. materials to determine their susceptability to cracking under the influence of weld stresses. The weld stresses were introduced by making a circular weld configuration as shown in Fig. 12.

An 8 x 8 in. section of butt welded sheet material was circular punched to obtain a circular blank about 3 in. in diam. The 8 x 8 in. section was then framed with a 1 in. wide section of 0.125 in. stainless steel spot welded in place to make the section more rigid. The circular blank was then rewelded in its

Table 7—Resistance Spot Weld Tensile Shear, Nugget Size and Weld Schedules

Test no.	No. of coupons	Shear strength in lb Avg	Min	Range	Avg nugget diameter, in.	Avg penetration, %	Weld Schedule Preheat	Weld and Temper	Squeeze	Hold	Force	Phase A	Electrode RWMA Class 2
[illegible]	15	58	40	30	0.044	60	10[1]	10[1] 10[1]	20	20	93	..	5/8 in. diam 4 in. face radius
	(0.005 René 41 to 0.005 René 41)												
[illegible]	15	44	30	20	0.034	1	...	15[1] ...	27	7	151	off	5/8 in. diam 4 in. face radius
	(0.005 René 41 to 0.010 René 41)												
[illegible]	15	44	40	10	0.047	36	...	10[1] ...	27	..	134	off	1/2 in. diam 4 in. face radius
	(0.005 Hastelloy X to 0.005 Hastelloy X)												
[illegible]	15	41	35	10	0.062	38	...	10[1] ...	27	7	134	off	1/2 in. diam 4 in. face radius
	(0.05 Hastelloy X to 0.010 Hastelloy X)												
[illegible]	15	2196	2035	275	0.190	40	38[2]	51[3] 45[4]	4	..	2000		5/8 in. diam 5 in. face radius
	(0.040 René 41 to 0.040 René 41)												
[illegible]	16	2095	2000	200	0.22	48	38[2]	41[5] 52[6]	4	2	2000		5/8 in. diam 5 in. face radius
	(0.040 Hastelloy X to 0.040 Hastelloy X)												

Note	Interface	Pulse	Interval
1	1	1	1
2	1	7	7
3	3	7	7
4	2	1	8
5	5	10	7
6	2	8	8

Preheat, weld and temper are in %; phase shift squeeze and hold are in cycles.

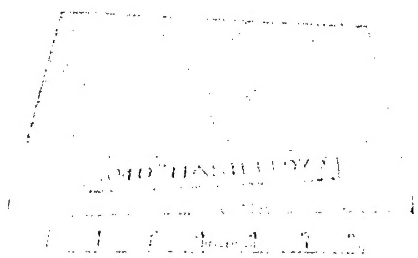

Fig. 12—0.040 in. Hastelloy X, circular restraint weld (test 24)

original position forming a circular weld insert.

Radiographs made of the welded parts showed no apparent cracking. The parts were then aged and re-radiographed. No apparent cracks were found after aging, although the plates had warped considerably. The erratic warping may be attributed at least in part to the stainless steel framework which has thermal expansion properties lower than the nickel-base alloys. These tests indicate a low susceptibility of René 41 and Hastelloy X material to cracking from restrained stresses.

Spot Welding Test Results

Spot welding test results and the weld schedules used to obtain the results are summarized in Table 7. Tests 25 28 were made to determine the weldability of the foil material. Evaluation of the mechanical test data and the photomicrograph of tests 25 and 28 of Fig. 13 indicate the weldability of the two alloys is good. It is necessary to have low heat input, long heat time and high pressure to produce the weld with the required nugget diameter without expulsion.

The good weldability has been proved only with resistance welding equipment of a precision type, 3-phase, with separate phase shift and timing controls for preheat, weld and post weld functions.

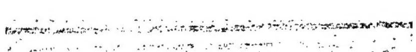

Fig. 13—0.005 in. Rene' 41 acceptable spot weld (test 25); 0.005 in. to 0.010 in. Rene' 41 unacceptable spot weld (test 26); 0.005 in. to 0.010 in. Hastelloy X acceptable spot welds (test 28)

Test 26 of Fig. 13 shows a lack of penetration in the thinner sheet and is not considered an acceptable weld. The fault can b corrected by d creasing the face radius of the elect de contacting the thinner sheet, and increasing the face radius of the electrode contacting the thicker sheet.

Good spot welds can be obtained in the 0.040 in. gage material without difficulty. In order to obtain the desired weld nugget diameters and to prevent expulsion, it is necessary to use high pressure and relatively long heat times. Figure 14 shows a case of slight expulsion of a segregate material at the faying surface, and an area of coring or incipient melting adjacent to the faying surface projected from the boundary of the nugget. Figure 15 shows a complex pattern of segregation. These conditions were found in both alloys but they had little if any effect on the strength of the welds. Other investigators have identified the segregate as a eutectic. Thei. work indicates that their presence resulted in lower property values.

Cleaning Procedures

It was not the intent of this project to develop cleaning procedures for production purposes. The methods tried were on a laboratory scale only for the purpose of adequate cleaning to produce consistent welding results.

As-received material was sheared to size, vapor degreased and pickled in the following pickling solution which removes light oxide, leaving a uniform matte surface:

Composition	Volume %
Proprietory fluoride solution	14
(42′ Be) nitric acid	34
Water	52

Treatment: 10 min immersion in solution at room temperature, water rinse and dry.

An attempt was made to evaluate the effects of cleaning Hastelloy X material by comparing the tensile shear results of 10 spot welded coupons, cleaned with Chemicals A and B, scale conditioners followed by pickling as previously mentioned. To eliminate as many variables as possible, each chemically cleaned coupon was spot welded, using the same welding schedule, to a coupon which had been manually abrasive cleaned.

Referring to Table 8, it is interesting to note that the coupon in the as-received uncleaned condition (No. 6) had a tensile shear strength of 1375 lb. The average tensile shear of the coupons cleaned by varying time and temperature in chemical solutions was 1680 lb, and the average tensile shear of 20 coupons cleaned with emery cloth was 20[illegible] lb. These results illustrate that a wide variation in shear strength occurs when a variation of cleaning methods are used. If reproducible results are desired, all material must be cleaned similarly.

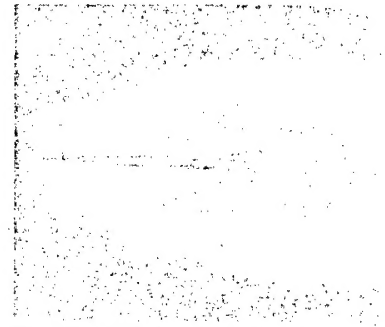

Fig. 14—0.040 in. Hastelloy X, spot weld containing segregate expulsion and coring or incipient melting (test 30)

Conclusions

Fusion welded René 41 and Hastelloy X materials in foil gages of 0.005 and 0.010 in. display good welding characteristics. Cleaning, edge preparation, precision fixtures and precision welding equipment are essential to produce sound welds. It is necessary to use inert gas backing to prevent excessive scaling and oxide formation, caused by elements in the atmosphere, when the material is at molten temperatures.

Both materials have satisfactory elongation properties and good ultimate and yield strength when welded in the solution heat treated condition. René 41 may be aged after welding if increased strenght is desired at the sacrifice of elongation. It may also be joined in the unrestrained condition after aging, resulting in a ductile weld having an ultimate strength of 140,000 psi.

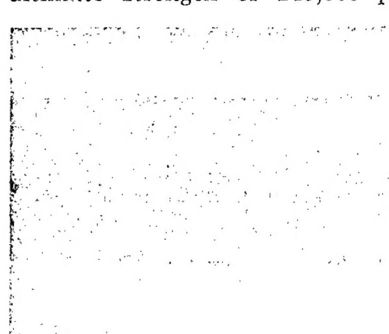

Fig. 15—0.040 in. Hastelloy X, spot weld containing complex segregation (test 30)

Table 8—Cleaning 0.040 in. Hastelloy X with Chemicals Prior to Spot Welding

Coupon no.	Prior condition	Cleaning Compound: Chemical A @ 265–275 °F, min	Cleaning Compound: Chemical B @ 200–210 °F, min	Chemical C: Time, min	Chemical C: Temp, °F	Tensile,[b] shear/lb
1	As received	30	30	25	120	1450
2	As received	...	30	20	120	1450
3	As received	...	45	23	135	1600
4	As received	30	45	23	135	1850
5	As received	60	60	25	120	1675
6	As received	...	...	...	...	1375
10	Vapor degrease and alkaline wash	...	...	16	90	1500
11	Vapor degrease and alkaline wash	...	45	25	120	1800
12	Vapor degrease and alkaline wash	45	45	25	135	1775
13	Vapor degrease and alkaline wash	...	...	25	120	1925
			Cleaned coupons avg 1680			
			Control[c] coupons avg 2095			

[a] HF-HNO_3 solution formulations.
[b] Spot welds made 72 hr after cleaning.
[c] Control—emery cleaned—20 coupons.

nd an estimated weld elongation f 20 to 30%. The effects of an aging heat treatment on Hastelloy X was to decrease the elongation without improving the strength potential.

The 0.040 in. gage materials display similar physical characteristics as the foil gages. With the exception of inert gas backing being required, production welding facilities and fixtures used for austenitic stainless steel are suitable for welding these two materials.

To comply with aircraft and missile radiographic standards, it is necessary to have clean material for welding. The material must be free of grease and scale. Pickling is the best method for removing heavy scale; however, sand or vapor blast may be used, followed by a light pickle to remove surface particles. Oil should be removed prior to welding by hot vapor degreasing. Shear edges should be draw-filed or machined to remove embedded particles that cause porosity.

Resistance welding requires the same surface cleanliness and fit-up as used for austenitic stainless steel. The welding equipment, however, must be three-phase and capable of higher pressures, greater accuracy and flexibility of control greater than the minimum requirement for stainless steel.

University Welding Research Directory

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